INDIAN STATISTICAL INSTITUTE
SQC & OR Unit, Hyderabad

MS in Quality Management Science : 2015-17

III SEMESTER : FINAL EXAMINATION

Subject : Industrial Experimentation

Date : 09th November 2016 Max. Marks : 100 & Time : 120 minutes

Instructions : This paper carries 120 marks. You need to answer all the questions and maximum marks you can score is 100. You need to provide all the answers on the normal answer booklet (Hardcopy). You may provide graphs/charts/diagrams etc. (if any) on the soft answer booklet [word file : Final Exam Answer Booklet (Student name).doc] by clearly writing your name on the answer sheet as well as file name.

1. State whether the following statements are correct or wrong with justification for your answer. (maximum 5 lines) (10x3 = 30)

a) Need for conducting designed experiments arises when the domain knowledge is more than adequate and the experimenter validates it for finding an optimal solution.

b) OFAT (One factor at a time) experiments are highly fractionalized saturated designs with higher order resolution where the interest is for studying only the main effects.

c) Parameter designs of Taguchi methods help in achieving robust products and processes by optimizing the control factors while eliminating the influence of the Noise factors.

d) Four 2 level factors and 3 interactions (any 3 of all possible the two factor interactions) can be studied with the help of L8 OA design.

e) In RSM conducting experiments at center points and axial points (at a distance of alpha $\leq \sqrt{K}$ where K is the no. of factors) ensures reduction in experimental efforts.

f) In regression modelling of the results of Design of Experiment the coded units of the design variables are used as against normal engineering units for simplifying the analysis procedure.

g) Fractional factorial designs are preferred over factorial designs when the objective of the experimenter is to quickly find optimal levels for the potential factors.

h) In design and analysis of experiments the most critical step is the "selection of an efficient design" as wrongly designed experiment result in sub-optimal solution.

i) Analysis of variance is not suggested in Taguchi methods as S/N ratio's normally do not have any replications so estimation of experimental error is not possible.

j) Success of a designed experiment depends on the superiority and complexity of the analysis methods adopted by the experimenter, such as selecting appropriate transformations, regression modelling, constructing the response surfaces etc.

2. A full factorial experiment was planned to be conducted to improve silver powder production process. The product is used in conductive pastes to manufacture a wide variety of products ranging from silicon wafers to elastic membrane switches. Powder density (g/cm2) and surface area (cm2/g) are the two critical characteristics of this product.

   The experiment involved three factors, 1. Reaction Temperature 2. Ammonium Percent and 3. Stirring Rate. Each of these factors had two levels and the design was replicated twice. The experimental data is given below,

Ammonium %	Stir Rate (RPM)	Temperature Deg.C	Density	Surface Area
2	100	8	14.68	0.4
2	100	8	15.18	0.43
30	100	8	15.12	0.42
30	100	8	17.48	0.41
2	150	8	7.54	0.69
2	150	8	6.66	0.67
30	150	8	12.46	0.52
30	150	8	12.62	0.36
2	100	40	10.95	0.58
2	100	40	17.68	0.43
30	100	40	12.65	0.57
30	100	40	15.96	0.54
2	150	40	8.03	0.68
2	150	40	8.84	0.75
30	150	40	14.96	0.41
30	150	40	14.96	0.41

   (a) Analyze the responses. Draw appropriate conclusions about the effects of the significant factors and interactions on the responses.
   (b) For developing a regression model what changes you need to incorporate in the factor levels. Develop the most appropriate model.
   (c) Perform suitable analysis for checking model adequacy and give your comments.
   (d) Draw and analyze the contour and surface plots. How these plots are useful for practical interpretation of the responses.

(e) Find the optimum combination of the design variables for getting maximum density and minimum surface area.

(f) What is the advantage of adding center points while conducting a two level factorial design experiment?

(g) The experimenter conducted three additional center runs (experiments) and the experimental data is given below;

Ammonium %	Stir Rate (RPM)	Temperature Deg.C	Density	Surface Area
16	125	24	18.00	0.25
16	125	24	18.10	0.27
16	125	24	17.90	0.26

(h) Analyze the data, draw response plots and give your inferences.

(i) Find the new optimum combination of the design variables.

(5+5+3+5+4+2+5+4+2 = 35)

3. The R&D team of a pharmaceutical company decided to conduct a series of optimization studies for improving a very low yield of one of the most important product. Temperature and Time were identified as the two critical process variables for the optimization studies.

The R&D team decided to conduct the optimization studies using response surface methodology. Immediately after conducting the experiments the computer of the R&D lab developed some problem and the team could extract the following partially filled tables with a great amount of difficulty but fortunately the results were all intact.

You as a newly recruited statistical expert asked to carefully study the tables, fill the blanks and perform a detailed analysis and suggest the optimal levels for the Temperature and Time.

(35)

Table - I

StdOrder	RunOrder	PtType	Blocks	Temperature	Time	Yield
1	1	1	1	225	55	33.95
2	2	1	1	235	55	36.36
3	3	1	1	225	75	35.00
4	4	1	1	235	75	37.25
5	9	0	1	230	65	35.45
6	10	0	1	230	65	35.75
7	11	0	1	230	65	36.05
8	12	0	1	230	65	35.30
9	13	0	1	230	65	35.90

Table - II

Step	Factors				Yield
	Coded		Actual		
	Temp	Time	Temp	Time	
Current	0	0	230	65	
1					36.50
2	4.80	2	254	85	39.35
3	7.20	3	266	95	45.65
4					49.55
5	12.00	5	290	115	55.70
6	14.40	6	302	125	64.25
7	16.80	7	314	135	72.50
8					80.60
9					91.40
10	24.00	10	350	165	95.45
11	26.40	11	362	175	89.30
12	28.80	12	374	185	87.65

Table – III

Step	Factors				Yield
	Coded		Actual		
	Temp	Time	Temp	Time	
1	-1	-1	345	155	89.75
2	1	-1	355	155	90.20
3	-1	1	345	175	92.00
4	1	1	355	175	94.25
5	0	0	350	165	94.85
6	0	0	350	165	95.45
7	0	0	350	165	95.00
8	0	0	350	165	94.55
9	0	0	350	165	94.70

Table - IV

Trials	Factors				Yield
	Coded		Actual		
	Temp	Time	Temp	Time	
1	-1	-1	345	155	89.75
2	1	-1	355	155	90.20
3	-1	1	345	175	92.00
4	1	1	355	175	94.25
5	-1.414	0			90.50
6	1.414	0			92.75
7	0	-1.414			88.40
8	0	1.414			92.60
9	0	0	350	165	94.85
10	0	0	350	165	95.45
11	0	0	350	165	95.00
12	0	0	350	165	94.55
13	0	0	350	165	94.70

4. The R&D team of an automobile company wants to improve the quality (Gloss) of the painted surface of the cars. Gloss reading of the painted surface need to be maximized. The team decided to conduct a designed experiment to achieve the maximum gloss at the same time robust against the environmental noise variables such as temperature and humidity. The experimental factors and their two levels are

Table 1 : Experimental Factors

Experimental Factors	**Name**	**Low Level**	**High Level**
A	Flow Rate	30	50
B	Pressure	3	5
C	Viscosity	10	15
D	Cure Temperature	120	160

The Two noise factors will be taken into account are the air temperature and humidity.

Table 2: Noise Factors

Noise Factors	Name	Low Level	High Level
N1	Air Temperature	15	30
N2	Humidity	30	90

Table 3: Experimental Layout and Results

					Noise Conditions			
				Temperature →	15	30	15	30
				Humidity →	50	50	90	90
					Gloss Readings (Response)			
Trial No	Flow Rate	Pressure	Viscosity	Cure Temp.	R1	R2	R3	R4
1	30	3	10	120	77	81	73	72
2	50	3	10	160	83	85	80	83
3	30	5	10	160	82	79	74	81
4	50	5	10	120	80	77	81	80
5	30	3	15	160	85	74	83	80
6	50	3	15	120	81	79	80	78
7	30	5	15	120	69	70	75	74
8	50	5	15	160	86	84	86	85

a. Given the design what are the interactions which can be estimated and studied.
b. Analyze the experimental data for mean as well as appropriate S/N ratio.
c. Suggest the optimum combination and predicted expected Gloss under optimum combination.
d. Considering the four noise condition responses as replicates and perform suitable analysis and suggest the optimum combination and predicted the expected Gloss.
e. Compare the results obtained in (d) with the results obtained earlier in b & c.

(20)